

REMARKS

After the foregoing amendment, claims 25-42, as amended, are pending in the application. Claims 1-24 have been canceled. Claims 25-42 are new. A substitute specification and a marked-up substitute specification are attached. Applicants submit that no new matter has been added to the application by the Amendment.

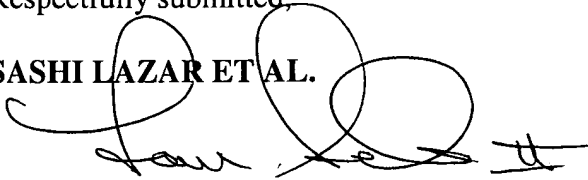
Entry of this amendment and early examination of this application are respectfully solicited.

Respectfully submitted,

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(Date)

By:



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Appendix B

~~Attorney Docket No. 9746-95U1~~

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TITLE OF THE INVENTION

5 [0001] Communication Protocol over Power Line Communication Networks

[0002] CROSS-REFERENCE TO RELATED APPLICATIONS

[0003] —This application is a continuation-in-part of U.S. Non-Provisional
Application No. 10/666,652 (~~Attorney Docket No. 9746-95US~~) filed
10 September 19, 2003 entitled “Communication Protocol over Power Line Communication
Networks.”

[0004] BACKGROUND OF THE INVENTION

[0005] —The present invention relates generally to power line communication
15 networks, and more particularly the protocols used for enabling and transmitting ~~various~~
~~media types and digital data at very high speeds~~ information over electrical power lines.

[0006] —Typically, ~~the~~ a power line communication network (PLC) is composed
of two components. The first component is the Wide-Area Power Line Network
(WPLN), which is the communication infrastructure that provides transmission of data
20 between the utility substations and ~~the~~ customer premise equipment typically located at,
or near by, the an electronic electric power meter at a customer premise. The second
component of the power line communication network is the Local Area Power Line
Network (LPLN), which is the communication infrastructure located at the customer
premise.

25 [0007] —~~All~~ The components of the power line communication network provide
one or more a bi-directional communication channels. Each channel is a point-to-point
link between a transmitter/receiver pair at one end of a transmission medium, composed
of a modulator/demodulator pair (MODEM), which initiates the transmission, a physical
medium which transmits ~~the high frequency signal~~ electrical signals, and a ~~terminating~~
30 ~~modem which receives the signal~~ second transmitter/receiver pair at a distant end of the

transmission medium. To implement a full duplex channel, each ~~modem~~
transmitter/receiver pair may act as a transmitter and a receiver simultaneously.

[0008] —In a typical configuration, the customer premise equipment includes a
device that ~~composed of~~includes two transmitter/receiver pairs ~~a modem pair~~. This
5 ~~device operates as a client modem of the WPLN~~ A first transmitter/receiver pair
communicates over the WPLN with ~~the an~~ an upstream modem transmitter/receiver pair
located at the utility substation, ~~as well as~~ A second transmitter/receiver pair ~~a head unit~~
~~for communicating~~communicates with all the end-user equipment located at ~~the~~ customer
premises. In essence, ~~this device~~ the second transmitter/receiver pair provides a single
10 point of entry into the customer premise LPLN.

[0009] —In addition of the physical infrastructure, the power line communication
network ~~must provide~~provides a resource allocation scheme that defines the policies and
procedures for inserting and removing devices into and from the power line
communication network. These resource allocation schemes are typically based on
15 different policies on the WPLN and the LPLN.

[0010] SUMMARY OF THE INVENTION

[0011] —Briefly stated, ~~in a first embodiment, the present invention defines the~~
~~communication infrastructure and protocols that enable high speed data communication~~
20 ~~over power line networks. The physical communication infrastructure comprises: the~~
present invention comprises power line communication system for communicating
information over a power line grid. The system comprises a first head-end unit and one
or more first hybrid units connected to the power line grid. The one or more first hybrid
units include a first client-end unit adapted to communicating with the first head end unit,
25 and a second head-end unit adapted to communicating with one or more second client-
end units.

~~a head-end modem device that provides a single point of entry into the particular~~
~~power line communication sub-network;~~

~~a physical transmission medium, composed of various power lines;~~

30 ~~a client end modem device that directly or indirectly connects customer premise and~~
~~end user equipment to the power line communication network.~~

~~—— In the second embodiment, the present invention defines the protocols used to establish logical communication between the physical elements defined in the first embodiment:~~

- ~~a protocol that facilitates the insertion of new physical network element into an already existing network,~~
- ~~a protocol that allows resource recovery following the extraction of an active network device from the already existing network,~~
- ~~a protocol that facilitates the reconfiguration of allocated resources among active devices attached to the already existing network.~~

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[0012] BRIEF DESCRIPTION OF THE DRAWINGS

[0013] —The foregoing summary, as well as the following detailed description of the preferred embodiments of the invention, will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, there are shown in the drawings embodiments that are presently preferred. It should be understood, however, that the invention is not limited to the precise arrangement and instrumentalities shown. In the drawings, like numerals are used to indicate like elements throughout. In the drawings:

[0014] —FIG. 1 is a graphical illustration of the full-duplex communication channel between the a head-end unit and various client-end units.

[0015] —FIG. 2 is a graphical illustration of a hybrid data transmit and receive unit, which functions as a client-end unit on one sub-network and the head-end unit on another.

~~—— FIG. 3 is a graphical illustration of the time division multiplexing and time slice allocation scheme used in the present invention.~~

[0016] —~~FIG. 4 is a graphical illustration of the protocol transition states for frame reception over the power line communication network.~~——~~FIG. 53. is a graphical illustration of the protocol transition states~~flow diagram of ~~for device insertion into the power line communication network.~~

[0017] —~~FIG. 64 is a graphical illustration of the protocol transition states of the head-end unit for~~flow diagram of ~~detecting inactive client-end devices.~~

[0018] —FIG. 75. is a graphical illustration of a typical power line communication network over AC power lines, including illustrations of the most common media applications.

5 [0019] —FIG. 8-6 is a graphical illustration of the frame and packet format used by the power line communication network.

[0020] FIG. 97. is a graphical illustration of a typical power line communication network over a DC power lines, including illustrations of the most common media applications.

10 [0021] _____ DETAILED DESCRIPTION OF THE INVENTION

[0022] —The present invention describes both the physical and logical characteristics of a power line communication network, related to high speed digital data transmission systems.system.

15 [0023] —Fig. 1 shows a preferred embodiment of a wide area power line communication network (WPLN) comprising a head-end unit 1, a power line grid 2 and one or more client-end units 3.The physical transmission medium is composed of three basic parts: a transmitter unit 4 that sends modulated digital data across various power lines, the power line grid 2 itself, which provides the transmission medium, and a receiver 7 that demodulates the signal sent by the transmitter. Although the electrical power grid is typically viewed as a shared bus medium, for the purpose of this invention, based on the nature of the transmission and reception rules, the power line communication network WPLN is viewed as a point-to-multipoint architecture. At the center of the architecture is the head-end unit 1, which is responsible – among many other things – to supervise for supervising access to the resources (i.e. the medium access control) for the entire a sub-network. The head-end unit 1 consists comprises of a pair of head-end transmitter module 4 and a head-end receiver 5-modules 5, each of which is tuned to different frequency bands, such that the two frequency bands do not overlap, nor do they interfere with one another.

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25

30 [0024] In addition to the head-end unit 1, there is one or more client-end units 3-3 attached to the electrical power line network WPLN. Although similar in hardware design, the client-end units 3 act as slave devices to the head-end unit 1. The Each

client-end units 3 ~~consist comprises~~ of a pair of client-end transmitter 6 and a client-end receiver 7 modules, tuned to different frequency bands, such that the two frequency bands do not overlap, nor do they interfere with one another.

[0025] —From a network topology point of view, there is a logical full duplex

5 communication channel between every client-end units 3 and ~~the~~ an associated head-end unit 1 of the PLC-WPLN network. This logical bi-directional communication path is actually composed ~~by~~ of two half-duplex channels, one from the head-end unit 1 to each client-end unit 3 (downstream path) 8, and another from ~~the~~ each client-end units 3 to the head-unit 1 (upstream path) 9. These half-duplex channels are implemented by tuning
10 the frequency of the client-end units' receiver module's ~~7-7~~ frequency to the transmit frequency of the head-end unit 1. Similarly, the head-end unit's receiver module 5 is tuned to the exact same frequency as the transmitter module 6 of each of the client-end units 3.

[0026] —~~This~~ The described dual uni-directional configuration has three

15 advantages. First, the ~~total allowable bandwidth~~ frequency bands in both the downstream and upstream directions are mutually exclusive, unlike typical local area network (LAN) and wide area network (WAN) environments where all the traffic shares the same transmission medium. Therefore the actual total throughput of the PLC-WPLN network is the sum of the downstream and the upstream communication channel's capacity.

20 Second, given the physical configuration of the network, the downstream communication path is guaranteed to be collision free. This eliminates the need for complex collision detection algorithms. Third, and perhaps most importantly, this frequency division scheme allows multiple head-end units 1 to be placed on the same physical electrical power line grid 2. However, it is important to observe that whereas these head-end units
25 1 are physically connected to the same ~~electrical power line grid 2~~, their transmit and receive frequency bands are mutually exclusive, therefore they are ~~thought of as two~~ separate sub-networks, each with its own set of client-end units 3. More specifically, ~~since each client-end unit 3 may be tuned to~~ generally communicates with only one the head-end unit 1 associated with its specific sub-network, ~~it is not possible to receive~~
30 ~~communication across these two (logically) separate networks~~. Nevertheless, this property provides virtually limitless bandwidth over the electrical power line grid 2. As

long as the transmit and receive frequencies are mutually exclusive and non-interfering, there are no restrictions on the number of logical sub-networks which can be overlaid on the same physical power line grid 2.

[0027] —Since on any given (logical) power line communication network there is only a single head-unit 1 with a single transmitter module 4, the downstream path is guaranteed to be collision free. The upstream pipe 9, however, is composed of a single head-end receiver 5 with multiple client-end transmitter 6 modules 6, all tuned to the same transmit frequency. If not carefully synchronized, the transmission of one client-end unit's 3 transmission can collide with other transmissions by other client-end units 3. To avoid collision on the upstream direction, the total upstream transmission bandwidth-epoch is divided into several smaller time slices slots-13. Preferably, Each time slice-slot has an equal transmit bandwidth-duration and may be assigned to no more than one client-end unit 3 at a time. Being assigned one or more time-slices slots permits the client-end units 3 to transmit in the upstream direction.

[0028] The allocation scheme by which client-end units 3 are assigned their individual time slots varies based on the network environment. In the WPLN network, time slot resources are typically assigned based on a pre-defined subscription rate. Since each time slot provides a fixed amount of channel capacity ~~guarantees a minimum constant bit rate (CBR) service~~, time slot allocation of ~~wide area network~~ WPLNs ~~are~~ is based on the amount of premium paid by each end user. In addition, the preferred embodiment uses a dynamic allocation algorithm, in which resources are (re)calculated and (re)assigned each time a new client-end unit is inserted into the network, or an existing client-end unit is deactivated.

[0029] ~~In local area networks~~ the LPLN, where most of the devices are under the same administrative domain, unless they belong to a different class of service, bandwidth allocation is typically based on an “equal share” policy. In other respects, the WPLN and LPLN operate identically. In contrast to the subscription based policy, where time slot allocation is static, this scheme uses a dynamic allocation algorithm, in which resources are (re)calculated and (re)assigned each time a new device is inserted into the network, or an existing devices is deactivated.

[0027] ——— Whereas the time slot based transmission scheme can provide collision free communication for all client-end devices 3 registered with the head-end unit 1, the insertion of new devices, which do not yet have resources allocated to them, pose a challenge because these devices have not received any time slot allocation, and therefore
5 — by the rules of the protocol, — are not allowed to transmit data. To facilitate registering new ~~devices~~ client-end units to register with the head-end unit, one or more time ~~slices~~ slots may be reserved by the ~~network~~ WPLN and LPLN explicitly for new device registration. It is worth noting here, that ~~this registration time slots is not meant to be mutually exclusive, and therefore are~~ prone to occasional collisions, when one or more
10 client-end devices 3 send their registration information to the head-end unit 1 at the same time. However, random timeout and backup algorithms can be used to minimize collisions among new client-end units 3.

[0030]

[0028] ——— Referring now to Fig. 3, the protocol for new device insertion is shown
15 as follows:

[0029] ———

[0031] ———

a. ——— a. ——— the client-end ~~device~~ unit 3 continuously
monitors 30 the transmission medium, waiting for carrier detection 31;

20 b. ——— b. ——— when carrier has been detected, the client-end unit 3 waits for ~~any~~ a medium access control (MAC) supervisory packet 32, which contains the broadcasted time slot allocations ~~20~~ for all known client-end units 3;

c. ——— c. ——— upon receiving a MAC supervisory packet,
25 the new client-end unit 3 searches 34 the time slot allocation table for a record that matches its hardware address 35;

d. ——— d. ——— if ~~this~~ a matching record is located, the client-end unit 3 incorporates the time slot allocation record into its memory, and may begin transmitting data in the upstream direction ~~36~~ 36. ~~Otherwise~~ if the received
30 MAC supervisory packet does not contain a matching time slot allocation record, the client-unit passively returns to waiting for a new MAC supervisory packets 32, unless the pre-configured timeout expires 37, in which case the client-end unit sends a registration message 38 to the head-end unit 1 over the reserved registration time slots, and passively returns to waiting 32 for a new MAC supervisory frames ~~packet~~ 32.

[0032] It is worth noting here, that the head-end unit 1 may elect to deny the registration request from the client-end unit 3. This is an implicit denial of service, as since the head-end unit 1 does not send an acknowledgement downstream to the requesting client-end ~~device~~ unit 3. ~~It~~ The head-end unit 1 simply does not include a new allocation record in the table of broadcasted time slot allocations.

[0033] —When a dynamic time slot allocation scheme is used, it is important for the head-end unit 1 to detect when one or more client-end units 3 ~~have been deactivated~~ are inactive, so that the previously allocated time slot resources can be re-assigned to other, active, client-end units.

[0034] The protocol logic for detecting inactive client-end units 1 ~~is~~ as follows (see Fig. 4):

a. ~~a.~~ a. for each upstream time slot, the head-end unit 1 examines the received frame 40 to determine if the transmission contained ~~ed~~ any valid data 41 (note that client-end units 3 transmit empty-null frames during all their assigned time-slots, even when they have no actual data to transmit);

b. ~~b.~~ b. if the time slot ~~did~~ does not contain ~~a valid frame~~ valid data, the missing_slot counter is incremented 43 for the client-end device 3 to which the time slot was assigned;

c. ~~c.~~ c. if the maximum missing slot count ~~has been~~ is exceeded, the head-end unit 1 marks the client-end unit as “down” 45, and the client-end unit’s resource allocation record is removed 47 from the time slot allocation table broadcasted 48 downstream by the head-end unit 1; and

d. ~~d.~~ d. if possible, the previously allocated time slots are assigned to other, currently active, client-end units 3.

[0035] —It is imperative to the correct operation of this scheme that all client-end ~~devices-units 3~~ use to the most up-to-date time slot allocation scheme data sent by the head-end unit 1. Every client-end ~~device-unit 3~~ must be ready to receive and update its time slot allocation information based on the MAC supervisory packets broadcasted downstream from the head-end unit 1.

[0036] The protocol for re-configuring the local time slot allocation information for each client-end unit 3 is as follows:

a. ~~the client-end device 3 is continuously monitors the~~
~~downlink channel for waiting for valid a MAC supervisory packetframes;~~

5 b. ~~if the MAC supervisory packet frame contains any~~
MAC supervisory information, the client-end unit 3 searches the time allocation table contained in the supervisory ~~frame-packet~~ for a record that matches its own hardware address;

c. ~~if a matching record is found, the time slot~~
10 allocation record is immediately applied to the client-end unit's local configuration; and

d. ~~if no matching record was is found, the client end device must~~
immediately ceases transmission, and enters into a reset state;

~~otherwise, the time slot allocation record is applied immediately to the client end~~

[0037] —The lowest unit of the digital transmission is a frame 70. —The maximum
15 frame size is defined by the ~~bandwidth-time duration of each a~~ time slot, allocated to
Referring to Fig. 56, the frame ~~of the preferred embodiment comprises; is composed of:~~

a. ~~a flags field 71 that contains various MAC level~~
control information including a destination address,

b. ~~a length field 72 that specifiesed the number of~~
20 valid octets in ~~the a~~ payload,

c. ~~a cyclic redundancy check (CRC) field 73 that~~
contains ~~the a~~ CRC block calculated over the payload block before transmission,

d. ~~a payload 74, and~~

25 e. ~~possibly some unused frame bytes 75.~~

[0038] The payload of each frame contains one or more packets 76.

[0039] The packet format 76 of the preferred embodiment is shown in Fig. 6 and is defined as follows:

a. ~~a media descriptor field 77 that is used to classify the type~~
30 of packet, and

~~_____ b. _____ b. _____~~ a length field 78, which is the number of octets in the payload, following ~~that should be considered as part of the packet's payload~~ 79.

[0040] —Typically, the packet payloads ~~80-79~~ contain a protocol specific header 81 and data 82.

5 [0041] —The media descriptor field 77 contains information about the type of protocol that was used at the user to network interface (UNI) (~~user to network interface~~) to form the packet 76. This allows various forwarding hardware to provide a better quality of service based of the content type carried in the payload 79. For example, one of the pre-defined media descriptor values is used to indicate a MAC supervisory packet.

10 [0042] —The advantage of using this format is that it allows the PLC power line communication network to carry a virtually limitless set of media formats. These include, but not limited to, Internet Protocol (IP) data, automatic meter reading (AMR) information, digitized voice and phone services, digital television signal, digital video and surveillance streams.

15 [0043] —Referring now to Fig. 5, there is shown a diagram of a typical implementation of a PLC. To support one or more of ~~these~~ media service types, the head-end unit 1 located at the power line substation 50 is connected to a service provider's uplink. The type of the uplink and the protocol used ~~solely~~ depends on the type of service type being supported. For example, for IP networks, the substation would typically be equipped with a high-speed fiber data uplink 52, such as SONET or Gigabit-Ethernet. Similarly, to support digital phone and voice communication systems, the substation ~~must~~ would include a digital interface to a PBX or SS7 switch 51.

20 [0044] The signal from these uplinks is transmitted over the power line grid 56 from the head-end unit to the client-end units 3 located at each residential or commercial end-user's premises 55. It is worth noting here, that the signals are passed through 54 any transformer 53 located between the substation and the customer premise equipment (CPE) without regeneration. The CPE is actually a hybrid ~~PLC~~ network element 11, (see Fig. 2) which ~~functions includes~~ as a client-end unit 3 for the head-end 1 toward the substation, MAC logic 10, and a head-end unit 1 for the ~~local area network~~ LPLN 57
30 inside of the customer premise.

[0045] The ~~local area network~~ LPLN 57 at the customer premise ~~consists~~ comprises of a single head-end unit 1, which is typically co-located with the power meter and an optional automatic meter reading (AMR) device 60, and one or more client-end units 3.

The client-end units 3 contain media-based adapters which enable a large variety of hardware to communicate over the power line communication network. For example, the PLN network adapter 61 allows personal computers 62 (PCs) to be connected to the ~~PLC-LPLN 57 network~~. Other adapters may include: digital television converters 63, which allow the reception of high-quality digital TV or cable service for television sets 64, voice digitizer and phone interface 65, which provides digital quality voice communication; facsimiles 66, ~~video adapters~~ converters 67, which allow cameras and other surveillance devices 68 to use the power line communication network.

[0046] —Notwithstanding the example applications described above, the power line communication ~~apparatus~~ system described in this inventions application can also be used over DC power lines. One example of this use is in the area of transportation, where various vehicles, such as trucks, automobiles, trains, are equipped with a variety of sensory equipment, such as break 87-89 and tire pressure 88-90 sensors for monitoring brakes 87 and tires 88.

~~[0046]~~ [0047] The analog signals captured by the sensors are digitized by the sensory input digitizer(s) 89 and 90, and through their associated client end units 3, the digital signal is transmitted over the DC power line 84 toward the head-end unit 1. Similarly, cameras and other image capture equipment may be attached to the vehicles, for example to assist the driver backing up. The analog signal converted by the camera 86 is digitized by the digital video converter unit 67, and its output is transmitted by the client-end unit 3 through the DC power line 84 toward the head-end unit 1. All data is transmitted to a central monitoring and recording unit 85 which is located at the head-end unit.

[0042] —It is foreseeable that the input data ~~monitored 85~~ collected by the head-end unit 1 may be transmitted to a centralized operation center or other vehicles in the area. This information is typically transmitted over wireless and/or satellite communication channels ~~91~~.

~~[0043]~~—[0048] Changes can be made to the embodiments described above without departing from the broad inventive concept thereof. The present invention is thus not limited to the particular embodiments disclosed, but is intended to cover modifications within the spirit and scope of the present invention.

Amendments to the Drawings:

The attached sheets of drawings include changes to Figs. 3-9. These sheets, which include renumbered Figs. 3-7, replace the original sheets Figs. 3-9 as follows:

Original Fig. 3 is deleted;

Original Fig. 4 is deleted;

Original Fig. 5 is renumbered Fig. 3;

Original Fig. 6 is renumbered Fig. 4;

Original Fig. 7 is renumbered Fig. 5;

Original Fig. 8 is renumbered Fig. 6; and

Original Fig. 9 is renumbered Fig. 7.

Attachment: Replacement Sheets